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(54) **SYSTEMS AND METHODS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING**

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H01P 1/22 (2006.01)
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CPC . ***H01P 1/38*** (2013.01); ***H01P 1/11*** (2013.01); ***H01P 1/39*** (2013.01); *H01P 1/222* (2013.01); *H01P 1/262* (2013.01)

(58) **Field of Classification Search**

CPC H01P 1/32; H01P 1/36; H01P 1/38
USPC 333/1.1, 24.2; 455/78
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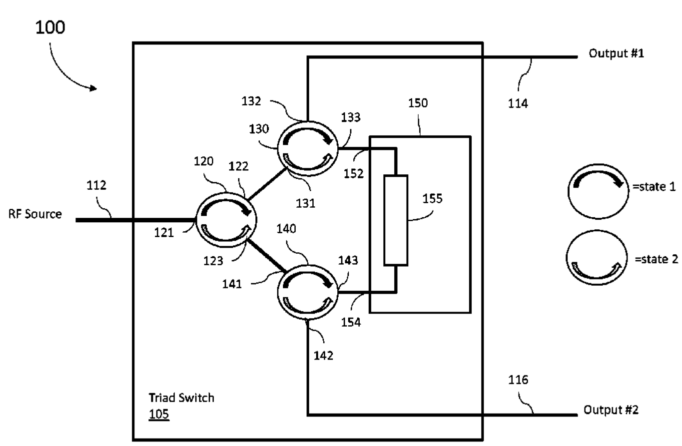
(57) **ABSTRACT**

Systems and methods for improved ferrite circulator RF power handling are provided. In one embodiment, a high power circulator switch comprises: at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator is coupled to an input of the triad switch; and a shared high power load having a first port coupled to the first circulator and a second port coupled to the second circulator.

20 Claims, 4 Drawing Sheets



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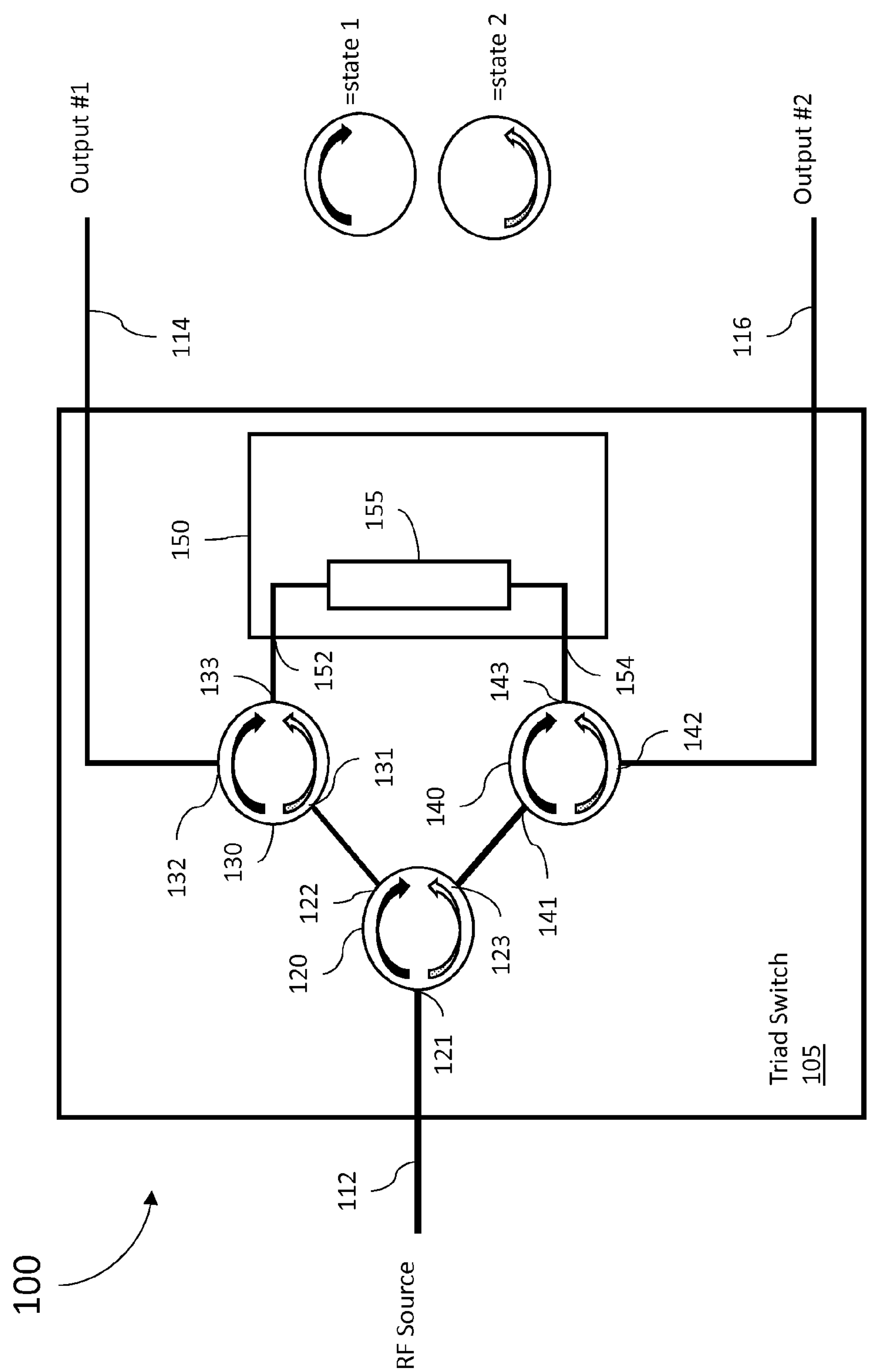


Output #1
=state 1
=state 2
Output #2
114
116
150
155
133
152
143
154
142
131
140
132
130
122
141
120
123
121
Triad Switch
105
112
100
RF Source

Fig. 1

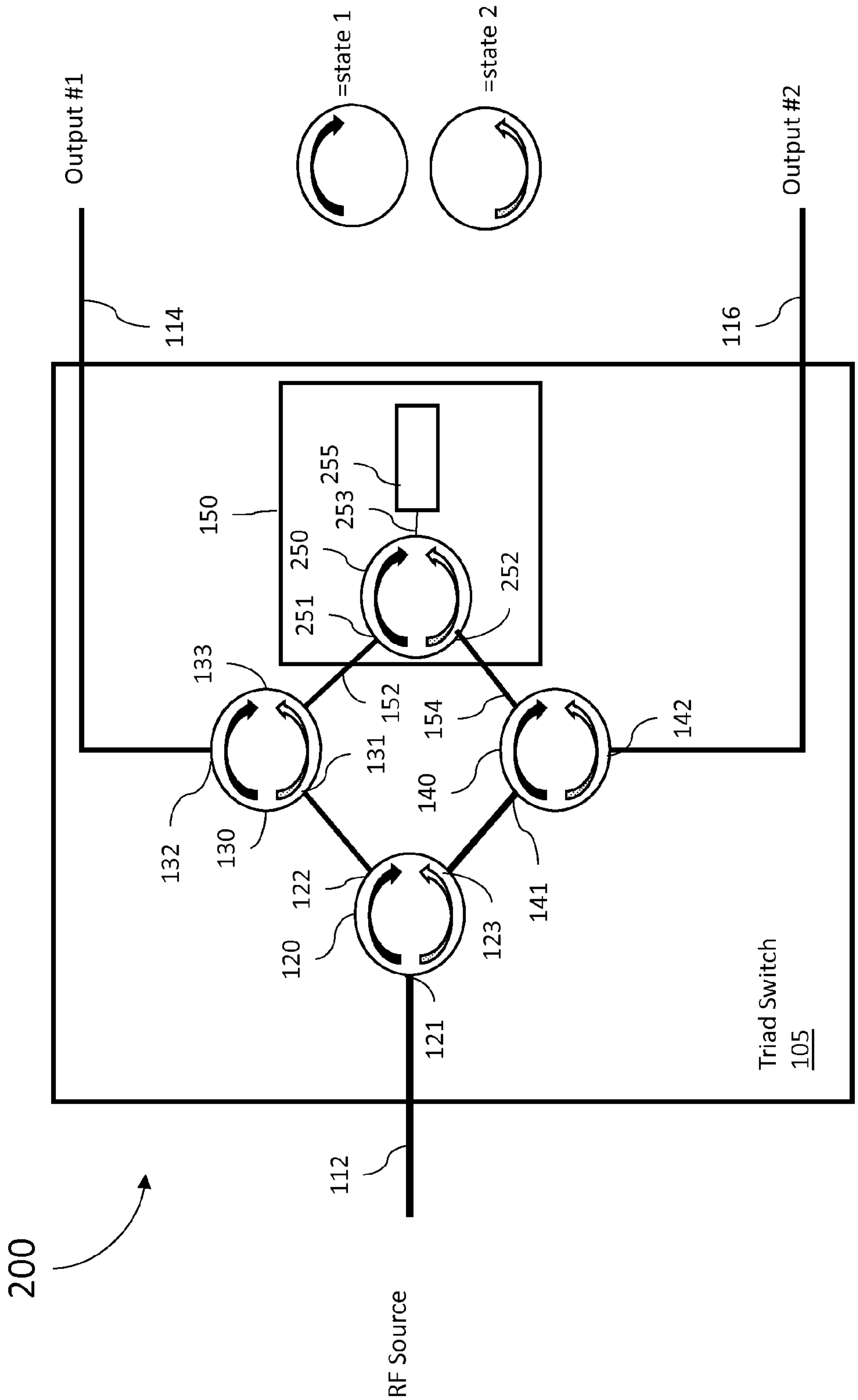

200
RF Source
112
Triad Switch
105
121
120
122
123
141
130
132
131
133
140
142
152
154
150
250
251
252
253
255
114
116
Output #1
Output #2
=state 1
=state 2

Fig. 2

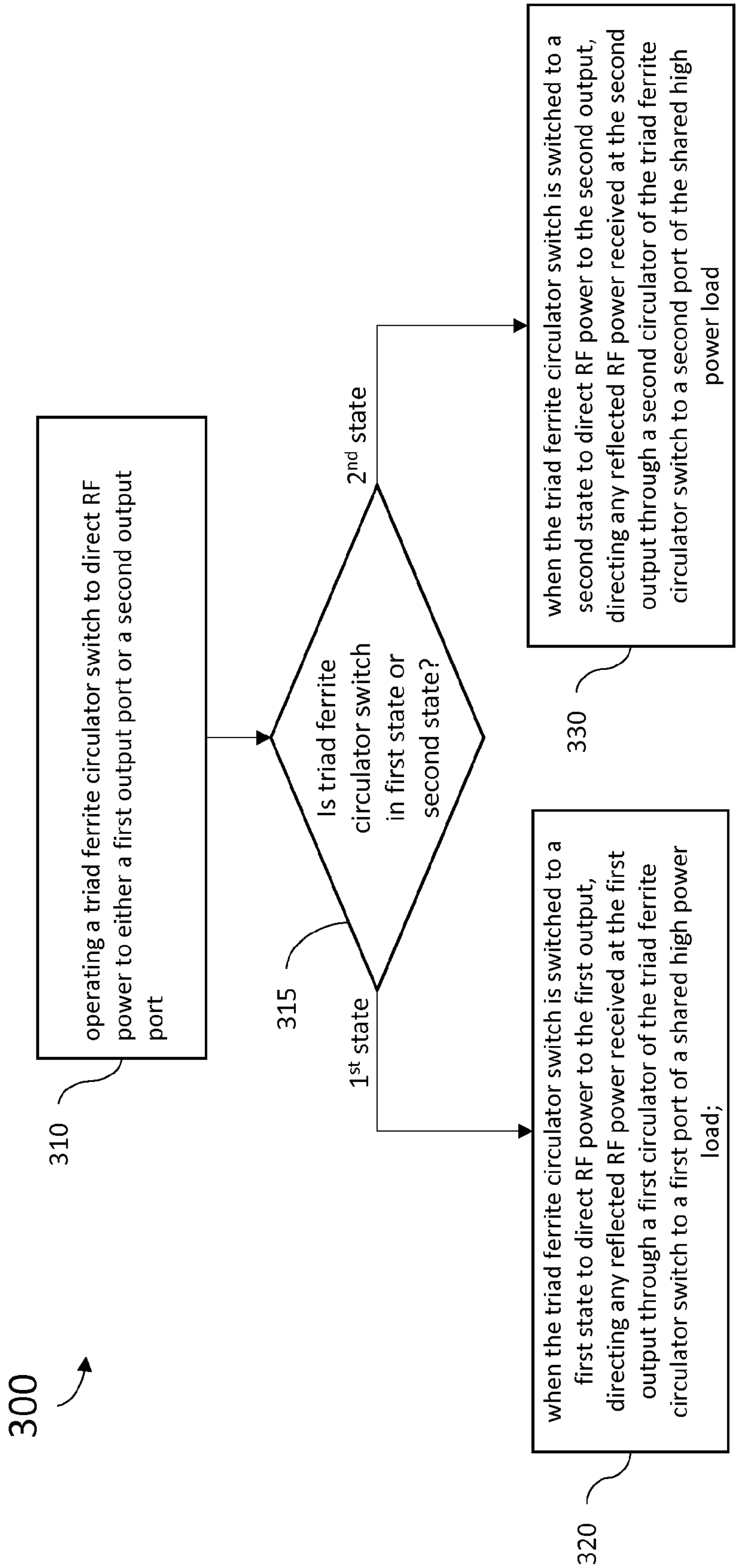
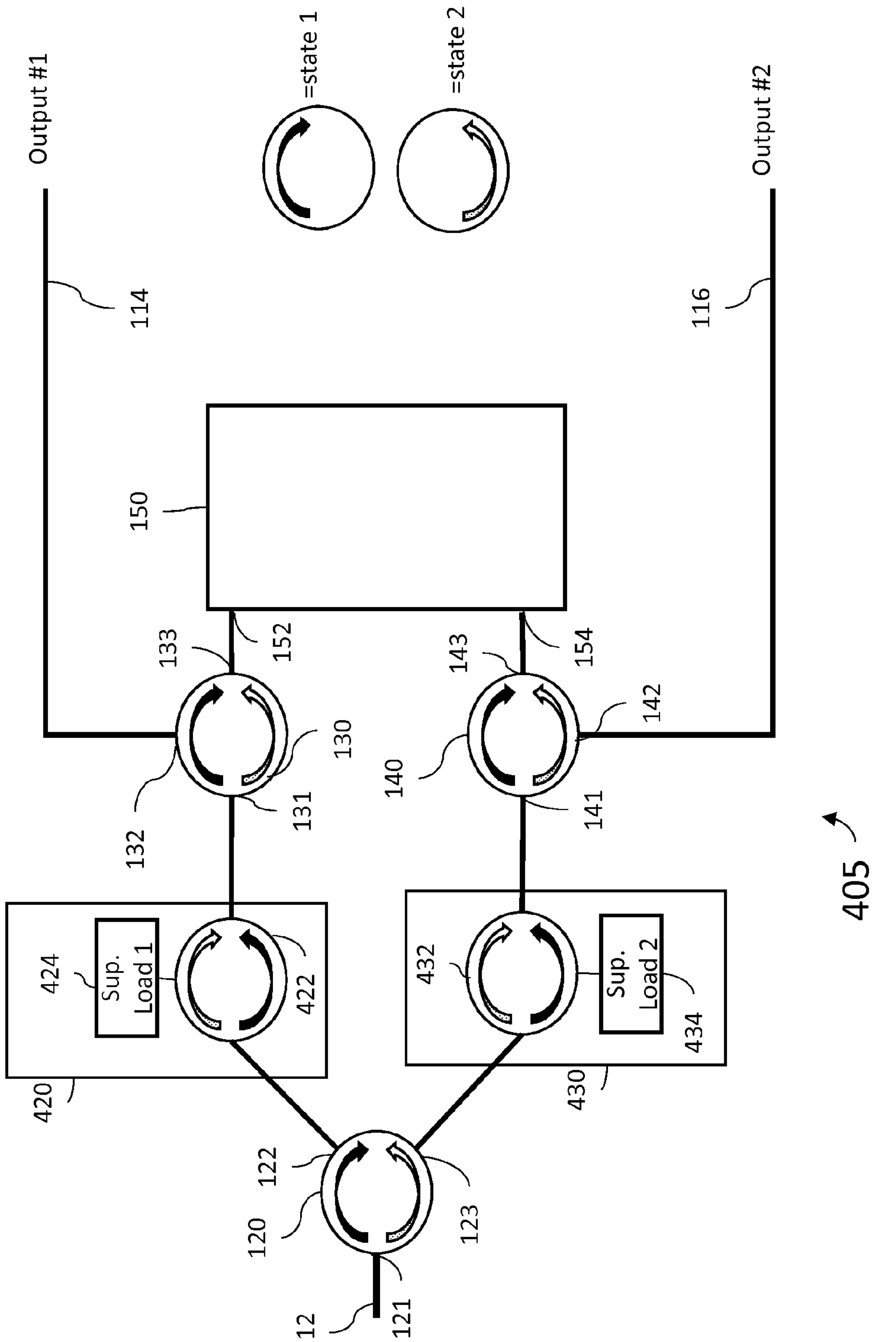

300
310
operating a triad ferrite circulator switch to direct RF power to either a first output port or a second output port
315
Is triad ferrite circulator switch in first state or second state?
1st state
2nd state
320
when the triad ferrite circulator switch is switched to a first state to direct RF power to the first output, directing any reflected RF power received at the first output through a first circulator of the triad ferrite circulator switch to a first port of a shared high power load;
330
when the triad ferrite circulator switch is switched to a second state to direct RF power to the second output, directing any reflected RF power received at the second output through a second circulator of the triad ferrite circulator switch to a second port of the shared high power load

Fig. 3



Output #1
=state 1
=state 2
Output #2
114
116
150
133
152
143
154
142
130
140
132
131
141
424
Sup. Load 1
422
432
Sup. Load 2
434
420
430
122
120
123
112
121
405

Fig. 4

SYSTEMS AND METHODS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING

CROSS-REFERENCE TO RELATED APPLICATIONS

This Application is related to U.S. patent application Ser. No. 14/247,452 entitled, "SYSTEMS AND METHODS FOR USING POWER DIVIDERS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING", filed on even date herewith, which is incorporated herein by reference in its entirety.

BACKGROUND

Ferrite switching circulators can be used to implement downlink beam hopping techniques in multibeam broadband satellite systems, where a single high power RF input can be quickly switched to multiple output antennas. A single 3-port ferrite circulator switch, although simple to implement, compact and relatively inexpensive, has a downside in that if a short or open circuit occurs within a connected output port, or if an output port is not properly connected, then radio frequency (RF) power can be reflected back into the switch. This reflected power can travel back through the circulator, exit another port of the circulator, and energize equipment that should have remained de-energized. To provide isolation between switched output ports, designs have been introduced comprising a configuration of three multifunction waveguide ferrite circulators (sometimes referred to as a ferrite circulator "triad") which include three ferrite junction switches and two high power loads. In a triad design, one of two high power loads is coupled to a first circulator while the other high power load is coupled to a second circulator. The input to a third ferrite circulator is switched between two outputs, where the first output is coupled to the input of the first ferrite circulator, and the third circulator's second output is coupled to the input of the second circulator. In such a triad design, if a short circuit occurs on a connection to the output port of the first ferrite circulator, then the reflected RF power is reflected back into the circulator and directed to its high power load which serves to absorb the reflected RF power. Similarly, the high power load coupled to the second circulator will receive and absorb reflected RF power received back in from the output port of the second circulator. Since minimal reflected RF power is transmitted back to the third circulator, isolation between the two output ports of the triad is achieved.

In order to improve satellite throughput in satellite communications, specified RF power levels used by satellites have been on the rise. The increases in RF power level may come either through improvements in output power of the on-board high power transmitters or through the combining of several high power transmitters. For this increase in RF power level, the limitation in the triad switches is the power handling of the ferrite switches and high power loads. That is, the high power loads used by the triad switches need to be able to handle the full transmit power levels (which can be on the order of 50 to 500 watts, for example) in case of a short circuit at an output to the switch. The high power loads need to be capable of absorbing the full reflected input power, which typically translates into the need for the high power loads to be larger and heavier. In the design of satellite systems, however, the space available within the satellite is typically a premium resource, and any extra

weight has a direct detrimental effect in the cost associated with launching the satellite into orbit.

For the reasons stated above and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the specification, there is a need in the art for improved systems and methods for improved ferrite circulator RF power handling.

SUMMARY

The Embodiments of the present invention provide methods and systems for improved ferrite circulator RF power handling and will be understood by reading and studying the following specification.

Systems and methods for improved ferrite circulator RF power handling are provided. In one embodiment, a high power circulator switch comprises: at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator is coupled to an input of the triad switch; and a shared high power load having a first port coupled to the first circulator and a second port coupled to the second circulator.

DRAWINGS

Embodiments of the present invention can be more easily understood and further advantages and uses thereof more readily apparent, when considered in view of the description of the preferred embodiments and the following figures in which:

FIG. **1** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present invention;

FIG. **2** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present invention;

FIG. **3** is a flow chart illustrating a method of one embodiment of the present disclosure; and

FIG. **4** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present invention.

In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize features relevant to the present invention. Reference characters denote like elements throughout figures and text.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

Embodiments of the present invention address the needs of triad circulator junction switches to be able to absorb the full reflected input power through new switch designs. As explained below, a triad ferrite circulator switch couples input devices exclusively to one of two outputs. Embodiments of the present disclosure take advantage of the fact that only one high power load is truly required for triad switch operation.

FIG. **1** is a diagram generally at **100** illustrating a triad ferrite circulator switch **105** (also referred to herein simply as "triad switch" **105**) of one embodiment of the present disclosure. Triad switch **105** includes an input port **112** and two output ports **114** and **116**. Triad switch **105** functions as a switchable waveguide, receiving an RF energy wave at point **112** and switching the wave to either ports **114** or **116**. This switching is achieved while maintaining a high degree of isolation (e.g. >30 dB) between ports **114** and **116**. In the embodiment shown in FIG. **1**, triad switch **105** comprises a triad of ferrite circulators **120**, **130** and **140**. Input port **112** is coupled to an input **121** of a ferrite circulator **120** which is switched between two outputs **122** and **123**. The circulator **120** output **122** is coupled to the input **131** of ferrite circulator **130**, while the circulator **120** output **123** is coupled to the input **141** of ferrite circulator **140**. Port **132** of ferrite circulator **130** serves as the first output port **114** of triad switch **105** while port **142** of ferrite circulator **140** serves as the second output port **116** of triad switch **105**. In this disclosure, the ferrite circulator **130** coupled to first output port **114** may be referred to as the "first circulator **130**", the ferrite circulator **140** coupled to second output port **116** may be referred to as the "second circulator **140**", and the ferrite circulator **120** coupled to the input port **112** may be referred to as the "third circulator **120**."

In order to dissipate any reflected RF power received back into output ports **114** and **116**, triad switch **105** further comprises a shared high power load **150** which in this embodiment comprises a two port attenuating wave guide **155**. That is, the shared high power load **150** comprises a first port **152** coupled to port **133** of circulator **130** and a second port **154** coupled to port **143** of circulator **140**. The two port attenuating wave guide **155** may therefore be thought of as common to or shared by the two circulators **130** and **140**. Because shared high power load **150** needs to be well-matched to the load connected to circulator outputs **133** and **143** (for example, the return loss of load **150** should be greater than 15 dB) and because it needs to be a 2 port device with high attenuation (for example, having greater than 30 dB attenuation or through loss from port **152** to port **154** and vise-verse) it may also be considered as an attenuator or attenuator load.

Triad switch **105** has only two operating states. In state **1**, port **114** is "on" (i.e. port **114** is coupled to, and receives RF energy from, input port **112**) while port **116** is "off" (i.e., isolated from both the input port **112** and output port **114**). In state **2**, port **116** is "on" (i.e. port **116** is coupled to, and receives RF energy from, input port **112**) while port **114** is "off" (i.e., isolated from both the input port **112** and output port **116**).

Circulator **120** comprises a ferrite circulator waveguide that comprise the input port **121**, and the first and second output ports **122**, **123**. Depending on the selected state of triad switch **105**, the direction of circulation within circulator **120** is either clockwise (CW) or counter-clockwise (CCW), and an RF energy wave entering input port **121** flows either to the output port **122** or the output port **123**. For example, in the embodiment shown in FIG. **1**, when triad switch **105** is in the first state, circulator **120** directs energy through the circulator in a first direction to its first output port **122** and out to the first circulator **130**. When triad switch **105** is in the second state, circulator **120** directs energy through the circulator in a second direction to its second output port **123** and out to the second circulator **140**. Circulators **130** and **140** each also comprises ferrite circulator waveguides which include input ports **131** and **141**, respectively. Circulator **130** includes an output port **132** that serves as the first output port **114** of triad switch **105**, while circulator **140** includes an output port **142** that serves as the second output port **116** of triad switch **105**.

In one embodiment, this two-state operation is achieved by switching circulator **120** while circulators **130** and **140** are maintained in a fixed state. That is, when circulator **120** is switched to provide an output to circulator **130**, the RF energy is sent to output port **132** and first output port **114** of triad switch **105**. Any reflected RF power received back into port **114** will enter into circulator **130** and travel around the circulator in the first direction to port **152** of shared high power load **150**. When circulator **120** is switched to provide an output to circulator **140**, the RF energy is sent to output port **142** and second output port **116** of triad switch **105**. Any reflected RF power received back into port **116** will enter into circulator **140** and travel around the circulator in the second direction to port **154** of shared high power load **150**.

In other embodiments, this two-state operation is achieved by the coordinated switching of the three circulators **120**, **130** and **140**. In that case, when triad switch **105** is in the first state, circulator **130** is switched "on" so that RF energy entering input port **131** flows through the circulator in the first direction and then out through port **114**. While triad switch **105** is in this first state, any reflected RF power received back into port **114** will enter into circulator **130** and travel around the circulator in the first direction to the first port **152** of shared high power load **150**. When triad switch **105** is in the second state, circulator **130** is switched "off" Any energy entering input port **131** (which should be negligible since circulator **120** is switched to circulator **140** in this first state) flows around the circulator in a second direction (opposite direction to the first direction) to port **133** and is absorbed by shared high power load **150**. When triad switch **105** is in the second state, circulator **140** is switched "on", so that RF energy entering input port **141** flows through the circulator in the second direction and then out through port **116**. While triad switch **105** is in this second state, any reflected RF power received back into port **116** will enter into circulator **140** and travel around the circulator in the second direction to the second port **154** of shared high power load **150**. When triad switch **105** is in the first state, circulator **140** is switched "off" Any energy entering input port **141** (which should be negligible since circulator **120** is switched to circulator **130** in this second state) flows around the circulator in the first direction (opposite direction to the second direction) to port **143** and is absorbed by shared high power load **150**. As such, in this embodiment, the triad of switching circulators **120**, **130** and **140** are always switched in lock-step as a group.

In other of these embodiments, at any one instance in time, one, and only one, of the outputs **114** or **116** is ever switched to the "on" state. Similarly, at any one instance in time, circulator **120** is switched to provide RF energy to only one of the circulators **130**, **140**. In this way, triad switch **105** routes high power to only a single output at a time and the shared high power load **150** will need to absorb high power RF reflections from only a single output port at a time. Thus, the shared high power load will only ever need to absorb reflected power (for example, from a short circuit) from only one of the two outputs (**114** or **116**) at any one time. For this reason, the shared high power load **150** only needs to be rated to absorb the maximum possible reflected RF power from either output. Further, because shared high power load **150** is a shared load, for both output ports **114** and **116**, the need for separate loads for absorbing reflected RF power for each of the outputs **114** and **116** is avoided, saving space, weight and expense.

As mentioned above, in the embodiment shown in FIG. **1**, one option for implementing the shared high power load **150** is by using a two port attenuating wave guide **155** which functions as a double ended load that can absorb an RF energy wave that enters through either end. In one embodiment, the two port attenuating wave guide **155** comprises a tapered wedge design of absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide. In this way, the reflected RF power entering one side of the waveguide is essentially completely attenuated to a negligible power level before reaching the second side of the waveguide. In some embodiments, the two port attenuating wave guide **155** may comprise staggered waveguide paths so a portion of the waveguide used from each side is shared by the two ports, and a portion is not shared.

In the embodiment shown in FIG. **2**, shared high power load **150** is instead implemented using an additional circulator **250** coupled to a high power load **255**. In this configuration, the state of circulator **250** is also switched in lock-step at least with circulator **120** such that reflected RF power received at circulator **250** is always directed to high power load **255**. More specifically, when triad switch **105** is switched to its first state to direct RF power from input **112** to output **114**, any reflected RF power will be directed to port **152** of shared high power load **150** as described above. In this embodiment, reflected RF power directed to port **152** enters a first port **251** of circulator **250**, which in this switching state directs that power out port **253** and into high power load **255** where it will be absorbed. Conversely, when triad switch **105** is switched to its second state to direct RF power from input **112** to output **116**, any reflected RF power will be directed to port **154** of shared high power load **150**. In this embodiment, reflected RF power directed to port **154** enters port **252** of circulator **250**, which in this switching state now directs that power out to port **253** and into high power load **255** where it will be absorbed.

It should be appreciated that additional embodiments include multiple instances of triad switches such as switch **105** coupled together in various combinations to achieve different switching configurations. That is, the input port **112** of a triad switch may itself be coupled to a switched source of RF power. For example, input port **112** may be connected to the output port of an upstream circulator, or even to the output port of a prior upstream triad switch (which may, or may not, be a triad switch having a configuration such as shown with respect to triad switch **105**). In this way, a 1×4 switch configuration may be obtained, as an example, by coupling the respective input ports **112** of two instances of triad switch **105** to respective outputs of an upstream switching device which is coupled to the RF source.

FIG. **3** is a flow chart illustrating a method **300** of one embodiment of the present invention. In some embodiments, the method **300** may be implemented using any of the various embodiments and implementations discussed above with respect to triad switch **150**. In other embodiments, other variations on triad switch **150** may be utilized.

Method **300** begins at **310** with operating a triad ferrite circulator switch to direct RF power to either a first output port or a second output port. As mentioned above, a triad ferrite circulator switch comprises a triad of ferrite circulators, such as discussed above.

When the triad ferrite circulator switch is switched to a first state to direct RF power to the first output (checked at **315**), the method proceeds to **320** with directing any reflected RF power received at the first output through a first circulator of the triad ferrite circulator switch to a first port of a shared high power load.

When the triad ferrite circulator switch is switched to a second state to direct RF power to the second output (checked at **315**), the method proceeds to **330** with directing any reflected RF power received at the second output through a second circulator of the triad ferrite circulator switch to a second port of the shared high power load.

In this embodiment, the first ferrite circulator is coupled to the first output port, and the second ferrite circulator is coupled to the second output port. Further, a third circulator may be coupled to the input of the switch. The third circulator directs RF power it receives at the input of the switch to the first ferrite circulator when the switch is operating in the first state. When the switch is operating in the second state, the third circulator instead directs RF power it receives at the input of the switch to the second ferrite circulator. In the first state, the first circulator is configured to receive the RF power from the third circulator and send it to the first output port of the switch. While in this state, the first circulator will also direct any reflected RF power it receives at the first output port to the shared high power load, where it will be absorbed as described in any of the above embodiments. In the second state, the second circulator is configured to receive the RF power from the third circulator and send it to the second output port of the switch. While in this state, the second circulator will also direct any reflected RF power it receives at the second output port to the shared high power load, where it will be absorbed as described in any of the above embodiments. In some embodiments, the first and second circulators (i.e., those connected to the first and second output of the triad ferrite circulator switch, are fixed to always direct RF power received from the third circulator to the outputs of the triad ferrite circulator switch. In other embodiments, the first, second and third circulators are each controlled in a lock-step manner such that the triad ferrite circulator switch is operated in either a first state or a second state as described above.

For some implementations, the shared high power load utilized in method **300** may comprise a two port attenuating wave guide, such as the double ended waveguide **155** discussed above. In other embodiments, the shared high power load may comprise the combination of a fourth ferrite circulator coupled to a high power load, such as illustrated in FIG. **2**. In this configuration, the state of the fourth circulator (which may also be referred to as the "shared load circulator") is switched in lock-step with circulators of the triad circulator switch such that reflected RF power received at the shared load circulator is always directed to the high power load.

In either implementation, because shared high power load in method **300** is utilized to absorb reflected RF power for both output port of the triad ferrite circulator switch, the need for separate loads for absorbing reflected RF power for each of the outputs is avoided, saving space, weight and expense.

For any of the embodiments described herein, additional embodiments may include more triad switches that further comprise supplemental isolators intervening between the input coupled circulator (such as circulator **120**) and the two output coupled circulators (such as circulators **130** and **140**). FIG. **4** illustrates one such embodiment where a triad switch **405** comprises the same elements as triad switch **105**, but further includes supplemental isolators **420** and **430**. In the embodiment shown in FIG. **4**, supplemental isolator **420** comprises a circulator **422** coupled to a first supplemental load **424** and is positioned between circulator **120** and circulator **130**. Supplemental isolator **430** comprises a circulator **432** coupled to a second supplemental load **434** and is positioned between circulator **120** and circulator **140**. With respect to supplemental isolator **420**, in operation, RF power received from circulator **120** is directed through circulator **422** to circulator **130** and then to output **114**. With respect to supplemental isolator **430**, in operation, RF power received from circulator **120** is directed through circulator **432** to circulator **140** and then to output **116**. As before, any reflected RF power received at either output **114** or **116** is directed to waveguide power divider **165** and waveguide loads **152** and **154**. In the case where the primary loads **152** and **154** are unable to completely absorb the reflected RF power, the balance of that reflected RF power exits waveguide power divider **165** and is directed through circulators **130** and **140** to one or both of supplemental isolators **420** and **430**. Reflected power received at supplemental isolators **420** and **430** is then directed (by circulators **422** and **432**) to the supplemental waveguide loads **424** and **434** which will further attenuate the reflected RF power, thus providing additional isolation between output ports **114** and **116**. In still other embodiments, additional supplemental isolators, such as **420** and **430**, may similarly be coupled between the input coupled circulator **120** and the two output coupled circulators **130** and **140** to provide still further isolation.

Example Embodiments

Example 1 includes a high power circulator switch, the switch comprising: at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator is coupled to an input of the triad switch; and a shared high power load having a first port coupled to the first circulator and a second port coupled to the second circulator.

Example 2 includes the switch of example 1, wherein when the triad switch is switched to a first state, RF power received at the input is directed through the third circulator and the first circulator to the first output, and any reflected RF power received at the first output is directed by the first circulator to the first port of the shared high power load; and wherein when the triad switch is switched to a second state, RF power received at the input is directed through the third circulator and the second circulator to the second output, and any reflected RF power received at the second output is directed by the second circulator to the second port of the shared high power load.

Example 3 includes the switch of any of examples 1-2, wherein the shared high power load comprises a two port attenuating wave guide.

Example 4 includes the switch of example 3, wherein the two port attenuating wave guide is matched at the first port and second port to have a return loss of greater than 15 dB, and wherein the two port attenuating waveguide has a through loss between the first port and the second port of at least 15 dB.

Example 5 includes the switch of any of examples 3-4, wherein the two port attenuating wave guide comprises a tapered wedge design of absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide.

Example 6 includes the switch of any of examples 2-5, wherein the shared high power load comprises a fourth circulator coupled to a high power load; wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a first direction around the fourth circulator when the triad switch is switched to the first state; and wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a second direction around the fourth circulator when the triad switch is switched to the second state.

Example 7 includes the switch of any of examples 1-6, wherein the high power load comprises a wave guide matched to have a return loss of greater than 15 dB and provides an attenuation of the reflected RF power of at least 15 dB.

Example 8 includes the switch of any of examples 1-7, further comprising at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

Example 9 includes the switch of any of examples 1-8, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

Example 10 includes the switch of any of examples 1-9, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

Example 11 includes a method for switching RF power using a high power circulator switch, the method comprising: operating a triad ferrite circulator switch to direct RF power to either a first output port or a second output port; when the triad ferrite circulator switch is switched to a first state to direct RF power to the first output, directing any reflected RF power received at the first output through a first circulator of the triad ferrite circulator switch to a first port of a shared high power load; and when the triad ferrite circulator switch is switched to a second state to direct RF power to the second output, directing any reflected RF power received at the second output through a second circulator of the triad ferrite circulator switch to a second port of the shared high power load.

Example 12 includes the method of example 11, further comprising: absorbing the reflected RF power received at either the first port of the shared high power load or the second port of the shared high power load with the shared high power load.

Example 13 includes the method of any of examples 11-12, wherein the triad ferrite circulator switch further comprises a third circulator coupled to an input of the triad ferrite circulator switch, wherein the method further comprises: the third circulator directing RF power received at the input of the triad ferrite circulator switch to the first circulator when the switch is operating in the first state; and the third circulator directing RF power received at the input of the triad ferrite circulator switch to the second circulator when the switch is operating in the second state.

Example 14 includes the method of any of example 11-13, the shared high power load further comprising a two port attenuating wave guide.

Example 15 includes the method of example 14, wherein the two port attenuating wave guide is matched at the first port of the shared high power load and second port of the shared high power load to have a return loss of greater than 15 dB; and wherein the two port attenuating waveguide has a through loss between the first port of the shared high power load and the second port of the shared high power load of at least 15 dB.

Example 16 includes the method of any of examples 14-15, wherein the two port attenuating wave guide comprises a tapered wedge design of absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide.

Example 17 includes the method of any of examples 11-13, wherein the shared high power load comprises a fourth circulator coupled to a high power load; wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a first direction around the fourth circulator when the triad switch is switched to the first state; and wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a second direction around the fourth circulator when the triad switch is switched to the second state.

Example 18 includes the method of any of examples 13-17, wherein the triad ferrite circulator switch further comprises at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

Example 19 includes the method of any of examples 13-17, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

Example 20 includes the method of any of examples 13-17, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A high power circulator switch, the switch comprising:

at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator is coupled to an input of the triad switch; and

a shared high power load having a first port coupled to the first circulator and a second port coupled to the second circulator.

2. The switch of claim **1**, further comprising at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

3. The switch of claim **1**, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

4. The switch of claim **1**, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

5. The switch of claim **1**, wherein when the triad switch is switched to a first state, RF power received at the input is directed through the third circulator and the first circulator to the first output, and any reflected RF power received at the first output is directed by the first circulator to the first port of the shared high power load; and

wherein when the triad switch is switched to a second state, RF power received at the input is directed through the third circulator and the second circulator to the second output, and any reflected RF power received at the second output is directed by the second circulator to the second port of the shared high power load.

6. The switch of claim **5**, wherein the shared high power load comprises a fourth circulator coupled to a high power load;

wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a first direction around the fourth circulator when the triad switch is switched to the first state; and

wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a second direction around the fourth circulator when the triad switch is switched to the second state.

7. The switch of claim **6**, wherein the high power load comprises a wave guide matched to have a return loss of greater than 15 dB and provides an attenuation of the reflected RF power of at least 15 dB.

8. The switch of claim **5**, wherein the shared high power load comprises a two port attenuating wave guide.

9. The switch of claim **8**, wherein the two port attenuating wave guide is matched at the first port and second port to have a return loss of greater than 15 dB, and wherein the two port attenuating waveguide has a through loss between the first port and the second port of at least 15 dB.

10. The switch of claim **8**, wherein the two port attenuating wave guide comprises a tapered wedge design of absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide.

11. A method for switching RF power using a high power circulator switch, the method comprising:

operating a triad ferrite circulator switch to direct RF power to either a first output port or a second output port;

when the triad ferrite circulator switch is switched to a first state to direct RF power to the first output, directing any reflected RF power received at the first output through a first circulator of the triad ferrite circulator switch to a first port of a shared high power load; and

when the triad ferrite circulator switch is switched to a second state to direct RF power to the second output, directing any reflected RF power received at the second output through a second circulator of the triad ferrite circulator switch to a second port of the shared high power load.

12. The method of claim **11**, further comprising:

absorbing the reflected RF power received at either the first port of the shared high power load or the second port of the shared high power load with the shared high power load.

13. The method of claim **11**, wherein the triad ferrite circulator switch further comprises a third circulator coupled to an input of the triad ferrite circulator switch, wherein the method further comprises:

the third circulator directing RF power received at the input of the triad ferrite circulator switch to the first circulator when the switch is operating in the first state; and the third circulator directing RF power received at the input of the triad ferrite circulator switch to the second circulator when the switch is operating in the second state.

14. The method of claim **13**, wherein the shared high power load comprises a fourth circulator coupled to a high power load;

wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a first direction around the fourth circulator when the triad switch is switched to the first state; and

wherein the fourth circulator is configured to direct the reflected RF power to the high power load in a second direction around the fourth circulator when the triad switch is switched to the second state.

15. The method of claim **13**, wherein the triad ferrite circulator switch further comprises at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

16. The method of claim **13**, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

17. The method of claim **13**, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

18. The method of claim **13**, the shared high power load further comprising a two port attenuating wave guide.

19. The method of claim **18**, wherein the two port attenuating wave guide is matched at the first port of the shared high power load and second port of the shared high power load to have a return loss of greater than 15 dB; and

wherein the two port attenuating waveguide has a through loss between the first port of the shared high power load and the second port of the shared high power load of at least 15 dB.

20. The method of claim **18**, wherein the two port attenuating wave guide comprises a tapered wedge design of absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide.

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